THE EFFECT OF LOAD ON THE DETECTION OF AN UNEXPECTED STIMULUS IN A RAPID SERIAL VISUAL PRESENTATION TASK

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Abstract

A rapid serial visual presentation task (RSVP) was combined with the 'inattention' paradigm (Mack & Rock, 1998) to investigate the effect of cognitive load on the detection of an unexpected stimulus. In addition, the detection of an unexpected stimulus presented in conjunction with a distractor item, rather than target, was also investigated. Seventy four students of the University of Canterbury participated in one of five experiments. Participants either performed a high cognitive load version of the RSVP task, selecting items on the basis of colour and semantic category, or a low cognitive load version selecting items on the basis of colour only. On the final frame of the fourth and critical trial, an unexpected stimulus appeared in conjunction with either a target or distractor item. The level of inattentional blindness to the unexpected stimulus was the result of interest. No effect of cognitive load or presentation partner was found. The implications of the results for the load theory of attention and cognitive control are discussed, along with the potential future uses of the developed method.

The effect of load on the detection of an unexpected stimulus in a rapid serial visual presentation task

Do you think you would notice if a gorilla walked by? Would you notice if the person you were in conversation with was replaced by someone else? Most of us would answer these questions with certainty: yes, of course we would notice. However, research investigating the relationship between perception and attention suggests otherwise. Simons and Chabris (1999) found 44% of people failed to detect a gorilla walking through a basketball game they were watching because they were concentrating their attention on counting the number of passes made with the ball. This is just one of many demonstrations of *inattentional blindness* (IB), a term coined by Mack and Rock (1998) to refer to the failure to detect an unexpected suprathreshold stimulus while attention is otherwise engaged. Such failures of perception in the absence of attention led Mack and Rock to propose there is no conscious perception without attention.

Perception, attention, and awareness

For decades the relationship between perception, attention, and awareness has been extensively investigated and debated, with particular emphasis on the processes involved in attention. For the purposes of this thesis, the term *perception* is used to refer to both the voluntary and involuntary processing of information provided to us by our senses, and *awareness* to refer to the state of conscious knowledge that results once the perceptual information has been attended and processed to a level of conscious report (Lamme, 2003). *Attention* is the complex mechanism involved in selecting what information (from the multitudes available from the senses) is processed sufficiently to support conscious awareness (Desimone & Duncan, 1995). Furthermore, several researchers of attention and consciousness describe how top-down attention is necessary for the conscious detection of unexpected stimuli (e.g. Dehaene, Changeux, Naccache, Sackur, & Sergent, 2006; Koch & Tsuchiya, 2007; and Lamme, 2003). Therefore, attention can be considered as the necessary link between perception and consciousness. Furthermore, researchers agree that attention is a selection mechanism and that at some point in the processing of information, selection must occur (Lavie, 1995; Styles, 2006). However, there is no consensus regarding the particular point in information processing where this selection occurs.

Early versus late selection

There are two major camps in the debate over the locus of selection: those who argue for early selection, and those who argue for late selection. Broadbent (1958) proposed a filter theory of attention which argues for early selection of relevant information based on simple physical attributes. Broadbent's early selection filter theory proposes a bottleneck that occurs after the processing of physical features, which stops irrelevant information from being processed beyond its physical attributes. In contrast, J. Deutsch and D. Deutsch (1963) proposed a late selection theory that argues selection does not occur until after the semantic meaning of the information has been processed. Unlike early selection theories, late selection theories assume that perception is unlimited in processing capacity, and that the selection bottleneck occurs after full perception and immediately before response selection. Treisman (1960) proposed an intermediate position in which information about unattended stimuli is not completely filtered out but is 'attenuated' and provides weaker signals than the attended stimuli. Over the past four decades, a multitude of research has explored these theories (see Driver, 2001 for a review) without a resolution to the selection debate. However, recently Lavie and her colleagues (see Lavie, 2000; Lavie, Hirst, de Fockert & Viding, 2004) have proposed a load theory of attention and cognitive control that offers a possible resolution.

The load theory of attention and cognitive control

Lavie et al.'s (2004) load theory of attention proposes two mechanisms of selective attention that enable people to engage in goal directed selective attention. The first mechanism is involved in the perceptual selection of information. According to the theory, perception is limited in capacity, and perceptual "processing proceeds from relevant to irrelevant items until capacity runs out" (Lavie & Cox, 1997, p. 395). The perceptual selection mechanism operates so that when the attentional resources demanded by the primary task are high and exhaust all available perceptual capacity, irrelevant distractors are excluded from perception because no available perceptual resources remain to process them. However, when the primary task is low in perceptual load, not all of the perceptual capacity is engaged, and any unused capacity is obligatorily assigned to processing task irrelevant information. Therefore, the locus of the attentional bottleneck depends on the perceptual load of the task. Lavie et al. (2004) argue for early selection under conditions of high load, and late selection under conditions of low load because the unused resources available will have been applied to process even irrelevant information to a deeper level. Lavie and Tsal (1994) provide a review of the previous selective attention literature, and describe how the studies supportive of late selection typically involve tasks of low perceptual load, whereas studies supportive of early selection typically involve high perceptual load tasks. Further support for the role of perceptual load in selective attention has been found from studies that directly manipulate perceptual load, using a variety of tasks and paradigms.

Using a modified flanker task (B. A. Eriksen & C. W. Eriksen, 1974) that required participants to search for a target letter among distractors made of either the same letters (low load) or different letters (high load), Lavie and Cox (1997) demonstrated an effect of perceptual load on the magnitude of distractor interference in a visual search task. They found greater distractor interference in the low load condition than in the high load condition. Lavie (1995) reported that increasing the task relevant set size decreased distractor interference. She also showed an effect of perceptual load on distractor interference in a go/no-go task using a feature versus conjunction manipulation of perceptual load. She found greater distractor interference under low load, in which responses were made on the basis of a colour feature distinction, than high load conditions, in which responses were made to a conjunction of colour and shape features.

Perceptual load has also been found to affect levels of negative priming (Lavie & Fox, 2000). The term negative priming refers to the phenomenon in which reaction times to previously ignored stimuli are slowed. Lavie and Fox presented participants with pairs of prime-probe displays in which participants were required to ignore the prime display and decide if a target letter was present in the probe display. The perceptual load of the prime display was manipulated by increasing the number of letters presented in the prime display to create a high perceptual load display. On one third of the prime-probe pairs presented, the target letter was presented in both the prime and probe displays creating a negative priming situation in which the target is ignored prior to becoming the target. Lavie and Fox found that increased perceptual load in the prime display led to decreased negative priming effects.

However, it is important to note that studies investigating the effects of perceptual load that involve manipulations of set size may be confounded. Increases in set sizes have typically increase the perceptual saliency of the distractor at the expense of the target in the large set size (high load) conditions. This relationship between load and saliency makes interpretation of results difficult as salient objects, such as the sudden onset of a stimulus, can capture attention. Eltiti, Wallace and Fox (2005) investigated both the perceptual load and the saliency hypotheses of distractor interference in a series of distractor onset-offset experiments. The saliency hypothesis predicts greater distractor interference when the distractor is an onset rather than an offset. Eltiti et al. used a letter identification task in which a central circle of letters was accompanied by a distractor box. In the onset condition an empty distractor box was presented with a central fixation circle followed by the letter identification display which would then have a distractor letter presented in the distractor box. In the offset condition the distractor box accompanying the fixation circle contained a figure eight placeholder, which then became a distractor letter in the letter identification display. The results of the distractor onset conditions supported the perceptual load hypothesis, but those of the offset conditions did not, suggesting it is distractor saliency rather than perceptual load that determines distractor interference.

Furthermore, Chen (2003) suggests the extent of attentional focus may be a further confounding factor in many experiments on the perceptual load effect. The zoom lens model of attention (Eriksen & St. James, 1986) likens the focus of attention to a zoom lens that can vary in size. The tasks employed by Lavie and her colleagues (e.g. Lavie, 1995, Lavie & Cox, 1997) have, in majority, been restricted to those that use separate targets and distractors and thus the increase in load is often confounded with a widening of attentional focus. Chen found that when the focus of attention is narrowed around a single object in both high and low load conditions using a Stroop task, high perceptual load leads to greater Stroop interference, the reverse of the expected perceptual load effect. Therefore, although there is substantial evidence for a role of perceptual load in selective attention, Lavie's theory may be limited to situations in which the spatial extent of the focus of attention increases with the load level, and when the relevant and irrelevant task information belong to separate objects that are situated in separate locations.

Lavie has recently proposed a second mechanism of attention that is susceptible to memory load effects: she postulates an active mechanism of attentional control that is dependent on higher cognitive functions (Lavie et al., 2004). As the majority of attention research tasks require participants to respond only to relevant information and ignore irrelevant information, there needs to be a mechanism involved in ensuring accuracy of task performance. Lavie et al. describe how the cognitive functions of the frontal cortices are "crucial for maintaining task processing priorities between relevant and irrelevant stimuli in order to guide behaviour in accordance with current goals" (p341). As the load on cognitive control resources increases, the ability to control behavioural responses and performance accuracy decreases, leading to greater interference from irrelevant stimuli. Note, increases in cognitive control load act only when perceptual load is low. Furthermore, unlike increases in perceptual load which decrease distractor interference effects, increases in cognitive control load increase distractor interference effects.

Lavie et al. (2004) present a series of experiments in which they manipulate cognitive control load by manipulating working memory load. Participants were required to memorise either a single digit (low load) or a six digit memory set (high load) before performing a selective attention task in which a target letter and distractor letter were presented, followed by a recognition test. The results were supportive of the cognitive control load hypothesis, with greater distractor interference on the selective attention task occurring under high memory load conditions. A subsequent experiment investigated both working memory and perceptual load. The working memory load manipulation remained the same as in the previous experiment, and perceptual load was manipulated by increasing the relevant set size of the selective attention task display. The results supported both the perceptual and memory load hypotheses with greatest distractor interference in the low perceptual /high working memory load condition, and the least in the high perceptual/low working memory load condition. Furthermore, the results of the low perceptual/low working memory load condition in contrast with the high perceptual/high working memory load condition indicate perceptual load has primacy over cognitive load with the low load conditions resulting in greater distractor interference than the high load conditions.

However, Park, Kim and Chun (2007) propose a specialised load account, in which the level of distractor interference is dependent upon the interaction "between different types of dissociable processing mechanisms, each with independent, limited capacity (multiple resources)" (p. 1071). Using a same/different face-matching task, Park et al. manipulated the relationship between the working memory load and the target/distractor. Park et al. suggest the results indicate support for a specialised load account because working memory load led to impaired selection under target load conditions, but resulted in facilitated selection under distractor load conditions. Park et al. suggest that working memory load has an effect only when the same processing mechanisms are involved in processing both the working memory load information and the targets.

As mentioned earlier, Chen (2003) suggested the perceptual load mechanism may be limited to situations in which a wide focus of attention is required. A recent study by Gao, Chen, and Russell (2007) found evidence for the same limitation of the cognitive control mechanism. In a Stroop task, similar to that used by Chen (2003), Gao et al. manipulated the spatial extent of attention and working memory (by increasing the size of the memory set). The results showed that when the spatial extent of attentional focus is controlled, working memory load has little effect on distractor interference. Furthermore, Chen and Chan (2007) also investigated the correlation between working memory load effects and the extent of attentional focus. Their results were consistent with those of Gao et al., with working memory load having little effect on distractor processing when the extent of attentional focus is held constant.

However, it is important to note that the investigations described above all manipulated working memory load in their investigation of the cognitive control mechanism and load theory. Furthermore, the working memory load is not incorporated into the selection task, but is instead separate, creating a dual task situation. Two inattentional blindness (IB) studies (to be discussed in detail later) that incorporated working memory load into the selection task (Fougnie & Marois, 2007; Simons & Chabris, 1999) found working memory load facilitated selection rather than impaired it as predicted by Lavie et al. (2004).

Inattentional blindness

IB is a useful tool that can be used to investigate numerous aspects of attention and awareness such as the nature of attention: when it is object or space based, whether selection occurs early or late, and if selection is affected by load. It can also be used to explore the nature of attention capture, particularly the roles of stimulus meaning and attentional set. IB research has primarily relied on two paradigms, namely the 'selective looking' paradigm developed by Neisser and Becklen (1975) and the 'inattention' paradigm developed by Mack and Rock (1998).

Developed as a visual version of the dichotic listening task used to investigate auditory selective attention (e.g. Cherry 1953), Neisser and Becklen (1975) used the 'selective looking' paradigm to investigate sustained attention, and provided a demonstration of IB. Participants were required to attend to one of two superimposed video tapes, one of which depicted three people playing a basketball game, the other a hand-slapping game. Neisser and Becklen found that while participants were attending to one game, they often failed to notice an odd event that occurred in the ignored game. This method of investigating the detection of unexpected events is known as the 'selective looking' paradigm and was extensively used by Neisser and his colleagues.

More recently, Most and colleagues (see Most, Scholl, Clifford & Simons, 2005; Most, Simons, Scholl, Jimenez, Clifford & Chabris, 2001) have used variations of the 'selective looking' paradigm to investigate the roles of similarity and attentional set in IB. Most et al. (2001) found that 94% of participants detected the unexpected stimulus when it was the same colour as the selected task set. However, when the stimulus was the same colour as the ignored distractor set only 6% of participants reported seeing the unexpected cross stimulus. They concluded that featural similarity to the attended set enhanced detection. Most et al (2005) later expanded upon these findings, and suggested attentional set plays an important role in the detection of unexpected stimuli. The greater the similarity between the attended set and the unexpected stimulus and the greater the distinction between the distractor set and the unexpected stimulus, the more likely the unexpected stimulus will be noticed.

In addition to the research conducted with the ‘selective looking’ paradigm, IB has also been extensively studied using Mack and Rock’s (1998) ‘inattention’ paradigm. Typically the ‘inattention’ paradigm requires participants to engage in a highly demanding primary task that requires them to judge which arm of a briefly displayed cross is longer. They complete this task for three trials until, on the critical trial (the fourth trial), an unexpected critical stimulus is presented together with the cross in one of its quadrants. The critical trial is then followed by a divided attention trial and a full attention trial to ensure that the critical stimulus is detectable when it is no longer unexpected. Surprisingly, clearly suprathreshold critical stimuli fail to be consciously perceived by as many as 25% of participants in the critical trial when their attention was engaged on the primary cross task. Furthermore, Mack and Rock found IB (20%) to a black square critical stimulus that appeared on one of the arms of the primary cross task. Therefore, the critical stimulus occupied the same spatial location as that of the attended object, but was not detected by 20% of people.

However, several IB studies investigating attention capture have found that some shape and word stimuli breakthrough and capture attention. In particular, meaningful shape stimuli such as body silhouettes (Downing, Bray, Rogers, & Childs, 2004), and happy smiling faces (Mack & Rock, 1998) capture attention, resulting in reduced levels of IB. Furthermore, one's own name also captures attention (Mack & Rock).

Inattentional blindness and perceptual load

More recently, the 'inattention' paradigm has been used to investigate Lavie's load theory. Using a variation of the classic Mack and Rock (1998) 'inattention' cross task, Cartwright-Finch and Lavie (2007) investigated the role of perceptual load on IB. The cross task was modified so that the two arms of the cross were different colours (green and blue, as opposed to both black in Mack & Rock), and were slightly different in length. The low perceptual load condition involved a simple colour discrimination task, whereas the high load condition was a line-length discrimination task. The line-length discriminations were subtle and demanded "considerably more attentional resources" (Cartwright-Finch & Lavie, 2007, p.326) than the clearly distinctive colour discriminations. On the critical trial, a black outline square was presented concurrently with the cross. Cartwright-Finch and Lavie found 45% of participants in the low load condition were blind to the critical stimulus, while in comparison, 90% of participants in the high load condition failed to detect it. Thus, the results support the predicted effect of perceptual load, with greater interference and detection of distractors under low load conditions.

Inattentional blindness and cognitive load

However, the cognitive load component of Lavie's theory has not found consistent support from IB studies. For example, a sustained IB study conducted by Simons and Chabris (1999) used a variation of the 'selective looking' paradigm to investigate IB in dynamic events. Participants were presented with a video of two 3-person teams playing games with a basketball (either in black or white clothing). During the 75 second film of the ball games, either a man wearing a gorilla suit, or a woman carrying an umbrella would walk through the scene (lasting for 5 seconds). The task also included a load manipulation with half of the participants instructed to count the number of passes made by a specified team (selected by clothing colour). The other half of the participants was instructed to keep two separate counts of the number of bounce and aerial passes made by the attended team. This high load task involves both an increase in working memory load (keeping two tallies instead of one) and an increase in perceptual load (having to make perceptual discriminations between the aerial and bounce passes).

According to Lavie et al.'s (2004) load theory of attention, the increase in working memory load (and therefore cognitive control load) would lead to greater detection of the unexpected event because of a lack of cognitive resources to control the allocation of attention. However, the increase in perceptual load would lead to less detection because perceptual capacity would be entirely taken up with the primary task. However, under similar combined load manipulations (described earlier) Lavie et al. found perceptual load to take primacy over cognitive load, with results supporting the perceptual load predictions. Consistent with the results of Lavie et al., Simons and Chabris (1999) report results in support of the perceptual load predictions because increasing the task load led to greater IB of the event with

55% of participants in the harder condition blind to the unexpected events and only 35% in the easier condition.

Fougnie and Marois (2007) also investigated the effect of working memory load on IB. Fougnie and Marois combined a classic Mack and Rock (1998) IB cross arm task with a working memory load manipulation, creating a dual task situation, similar to that used by Lavie and colleagues. However, unlike Lavie et al. who manipulated memory load by increasing memory set size, Fougnie and Marois manipulated working memory load by having participants in the low load group simply remember a set of five consonants while performing a selective attention task, whereas those in the high load group were required to rearrange the set of five consonants into alphabetical order, while performing the selective attention task. The results of this study were not consistent with the predictions of the cognitive control load mechanism presented by Lavie and colleagues (2004); participants in the high working memory load condition showed greater rates of IB to the unexpected stimulus (68%) than those in the low load condition (35%).

To date, the cognitive control load predictions on IB have only been investigated by manipulating working memory load. However, semantic activation has also been suggested to increase cognitive load (Lavie, 1995), and furthermore letter categorisation appears possible only when adequate attentional resources are available (Otsuka & Kawaguchi, 2007). The present research seeks to investigate the cognitive load predictions of Lavie's theory on the level of IB using a semantic category manipulation of cognitive load using a rapid serial visual presentation (RSVP) task, similar to those which have previously been used to investigate other perceptual phenomena such as attentional blink, and repetition blindness.

The RSVP paradigm

A typical RSVP task requires participants to monitor a rapid stream of stimuli for targets, to which they must respond as quickly as possible, and is thought to tap purely perceptual processes (Mitchell, 1979). In a seminal study, D. Broadbent and M. Broadbent (1987) discovered the phenomenon known as *attentional blink* when they used an RSVP task to investigate the identification of multiple target words. They found that following the presentation of a target, attentional processing is limited and people are often unable to report the items following the target, however the item directly following the target usually escapes attentional blindness. Therefore, when two targets are presented within 500ms of each other and separated by one or more distractors, the second target may fall within an attentional blink and be missed.

More recently, variations of the RSVP task have been used to investigate IB. Rees, Russell, Frith, and Driver (1999) measured brain activity while participants viewed rapid displays each consisting of a letter string or word superimposed over a picture. Participants were instructed to monitor for repetitions in either the stream of letter strings or the stream of pictures being displayed. Rees et al. argued that if participants were truly 'blind' to unattended stimuli then the brain activation levels for words and non-words should be indistinguishable. In contrast, if the ignored words are processed then the activation levels to ignored words and non words should be discernibly different (Rees et al., 1999). They found no difference in activation levels to ignored words and non words, indicating that participants were blind to orthographic and/or meaning differences between them. However, Ruz, Worden, Tudela, and McCandliss (2005) conducted a replication of the Rees et al. study using event-related potentials to measure brain activity instead of fMRI. Their results indicate words continue to be processed even when attention is otherwise engaged as different patterns of activity were produced by words and random letters strings when ignored. Furthermore, another very close replication of the Rees et al. procedures has used a negative priming manipulation to assess the processing of ignored words. In this study an ignored picture name impeded the processing of the named picture on the next display in 1- and 2-back versions of the picture monitoring task (Russell & Neumann, personal communication), indicating that the ignored picture name had been processed.

Recently, the Rees et al. (1999) RSVP task, along with a rapid serial auditory presentation (RSAP) version has been used to investigate IB within and across sensory modalities in order to explore the allocation of attentional resources (Sinnett, Costa & Soto-Faraco, 2006). However, rather than using brain imaging to detect the processing of the unattended stimuli, Sinnett et al. conducted a word recognition test at the completion of the ten minute long monitoring task.
In both unimodal (target and cue were presented in the same modality) visual and auditory tasks, participants who attended to the word stream performed significantly better on the word recognition test than those who monitored the picture (visual)/ animal sound (auditory) stream, indicating IB to the ignored stream. Furthermore, participants in the crossmodal conditions (target and cue were presented in the different modalities) who attended the word stream (either visual or auditory) performed better on the word recognition test than those who monitored the picture or sound stream. A comparison of the IB levels between the unimodal and crossmodal conditions indicates attentional resources are shared across the sensory modalities rather than each of the senses having their own pool of resources. However, these conclusions should be treated with caution as a word recognition

test at the end of a ten minute long task is not an adequate measure of IB; the words could have been perceived but forgotten due to the rapid decay and limited capacity of working memory (Mack & Rock, 1998).

Scholte, Witteveen, Spekreijse and Lamme (2006) used an RSVP task in conjunction with a texture segregation variation of the Mack and Rock (1998) 'inattention' paradigm to investigate the level of scene segmentation processing under inattention. The task was to focus on a rapid serial presentation of white and black letters. Participants were required to indicate whether the white letters were consonants or vowels. In conjunction with the onset of each new white letter, a new background texture was presented. Scholte et al. measured brain activity with magnetoencephalography (MEG) and magnetic resonance imaging (MRI) while participants performed the task. Of interest were the differences in brain activity for those participants who reported detection of the background texture changes and those who failed to detect the texture changes. The results indicated different activation levels in early visual area 3a. Importantly, the RSVP task used by Scholte et al. successfully induced IB (50%) to background texture changes, suggesting letter RSVP tasks can be successfully combined in an IB paradigm and can be used to investigate attentional processing.

Aims of the present research

The goal of the present research is to investigate the cognitive control mechanism of attention proposed by Lavie et al. (2004) using an extension of the RSVP IB task used by Scholte et al. (2006). Lavie and colleagues (2004) argue that when the demands on the cognitive control mechanism are high, susceptibility to distractors is also high (at least in situations of low perceptual load) because the ability to control performance accuracy and behavioural responses is impaired. To date, investigations of the cognitive control mechanism have been limited to manipulations of working memory load, and studies have found conflicting results. Therefore, the cognitive control mechanism is in need of further investigation with a variety of manipulations to load cognitive control.

Lavie (1995) describes how processes such as "semantic activation, memory, response selection, and response execution are conceived as post-perceptual processes" (page 452). Therefore, a categorisation task involving semantic grouping would require semantic activation processes which, being post-perceptual processes, would load cognitive control resources. The present research aims to investigate the predicted cognitive load effects using a categorisation manipulation of cognitive control. The low load task requires a simple colour classification (red and black), whereas the high load task requires both a colour classification and a semantic classification (letter or digit). Jonides and Gleitman (1972) have shown letter and digit categorisation to be a post-perceptual process. They found the *alphanumeric category effect*[1], seen in visual search research, to be due to letter and digit stimuli being recognised as belonging to separate categories, rather than due to the subtle perceptual discriminations between the two groups. Thus, cognitive load is manipulated in the present research as the high load task involves a semantic categorisation of the letter/digit stimuli over and above the simple perceptual colour identification of the low load task.

The present research uses a new paradigm that combines a variation of the RSVP IB task used by Scholte et al. (2006) with the traditional inattention paradigm used by Mack and Rock (1998). The paradigm involves participants monitoring a

[1] The *alphanumeric category effect* refers to the visual search effect in which letter (and digit) targets are more readily found among digits (and letters) than among other letters (and digits) (Neisser, 1967).

rapid stream of letters and digits. The letters and digits can occur in two different colours (red or black) and at either of two locations (left or right of a central fixation cross). Participants were required to monitor the RSVP stream and respond to target stimuli. The low load task involves selecting targets on the basis of colour (responding to red items among black) whereas the high load condition involves selecting targets on the basis of both colour and semantic group (responding only to red digits among red letters and black letters and digits). On the final display in a critical trial, a black word or shape is presented in conjunction with a target or distractor in the unoccupied location. Participants are questioned immediately following the critical trial regarding detection and identification of the unexpected critical stimulus. Of interest is whether levels of IB vary as a function of cognitive control load in the direction predicted by Lavie's load theory of attention: participants will be more susceptible to interference from irrelevant distractors under high cognitive load conditions than under low cognitive load conditions.

A further consideration of the present research is to investigate the detection rates of critical stimuli presented in the absence of a target stimulus. Unlike previous IB experiments, the present research uses a paradigm which allows the critical unexpected stimulus to be presented in conjunction with either a target or distractor item. It is possible that IB to unexpected stimuli results not from the engagement of attention in a primary task, but from the processes involved in response execution (Wolfe, 1999). Previous IB studies have presented the unexpected stimulus in conjunction with the primary task and require participants to complete response execution for the primary task before they are questioned about the unexpected stimulus. For example, a traditional Mack and Rock (1998) cross task requires participants to report which of the two cross arms are longer before they are questioned about the unexpected stimulus. It is possible that this process of response execution causes 'amnesia' of the unexpected stimulus, preventing participants from reporting its presence (Wolfe). However, the paradigm used in the present research allows for direct investigation of the effect of response execution on the rates of IB. The RSVP task allows the unexpected stimulus to be present in conjunction with a target item (requires response execution) or a distractor item (does not require response execution), and therefore a direct comparison into the effect of response execution.

General Method

The initial goal was to investigate the effect of visual and later, auditory cognitive load on the detection of an unexpected visual or auditory critical stimulus using a modification of the Mack and Rock (1998) IB paradigm. This involved incorporating a cognitive load manipulation into an RSVP task similar to that used by Scholte et al. (2006) and included the proposal to subsequently extend this to a rapid serial auditory presentation (RSAP) version (to explore crossmodal awareness). However, before the effects of visual load on awareness of an auditory critical stimulus can be explored it is necessary to demonstrate first that increasing visual cognitive load facilitates reporting of unexpected visual critical stimuli in the RSVP task. Because the cognitive load manipulations explored in Experiment 1 had no effect on the reporting of visual critical stimuli in the RSVP task the auditory aspects of the planned study were not explored. What follows is confined to the RSVP task and awareness of unexpected visual critical stimuli. Nevertheless many features of the visual task are constrained because initially they were chosen to match what was possible in an auditory version. In particular, in order to keep the task conditions constant across all experiments, and allow for comparisons between the experiments, auditory stimuli accompanied all visual stimuli in all experiments, in the same manner as in Experiment 1.

The RSVP task was combined with the Mack and Rock (1998) inattention paradigm as follows. Participants completed three RSVP trial sequences in which the task was to detect target items. On the fourth trial, the last display included an unexpected critical stimulus in addition to a target stimulus. It was expected that awareness of the critical stimulus would be increased when the cognitive load of the RSVP displays was greater.

Participants in the low cognitive load condition performed a feature search task where they monitored the 28 stimulus RSVP stream for red items among black distractors (in the RSAP task they would have monitored for female voice items with male voice distractors). The high load condition employed a conjunction search where participants monitored red digits amidst a display containing red and black letter and black digit distractors (in the RSAP task they would have monitored for digits spoken by a female voice among distractors consisting of letters spoken by both a male and a female, as well as digits spoken by a male voice). On the fourth experimental trial a visual stimulus (one of three words or two shapes) was presented in addition to the final target of the trial (in auditory versions the word stimuli would have been spoken).

Participants

In all experiments, participants were students at the University of Canterbury who took part voluntarily in exchange for a chocolate bar and $2 instant lottery ticket. All participants gave signed consent in accord with procedures required by the university Human Ethics committee. Furthermore, all participants were naïve to the purpose of the experiment. In order to be included in the data analyses participants had to detect the critical stimulus under full attention conditions, and to perform the target detection task with an error rate of less than 10%.

Apparatus and Stimuli

All experiments were presented using Superlab for Windows 4.0.3 (Cedrus Corporation) with visual stimuli via a 17 inch computer monitor (1024 by 768 screen resolution and refresh rate of 60Hz). Participants' viewing distance was approximately 50cm from the computer screen, the centre of which was at approximately eye level. Target responses and their response times were recorded via a mouse (with track ball removed) connected through the COM1 port, and a standard 102 key keyboard (keys "x" and ".") was used to record responses to follow-up questions.

Visual stimuli for the RSVP task were created using Superlab, and were always displayed on a white background. Fixation was indicated by a black cross measuring 0.38° visual angle and was presented in the centre of the screen (see Figure 1). Visual stimuli were formed from the following set of upper case letters B, C, D, E, F, J, K, L, N, P, R, T, X, Y, Z, and digits: 2, 3, 4, 5, 6, and 9. All visual stimuli were presented in Arial font in either black or red (RGB 255, 0, 0). From the viewing distance visual stimuli had visual angles measuring 0.57° in height and 0.48° in width measured at the widest point. Stimuli appeared at either the left or right of the fixation cross, with horizontal eccentricity of 2.39° (measured from the centre of the fixation cross to the centre of the stimulus item). Each trial in an RSVP sequence comprised a total of 28 stimulus items. The number of target stimuli per trial varied from 3 – 5, and the number of distractors separating the targets varied from 3 – 9. The final stimulus of each trial was equally likely to be either a target or a black distractor. Variation in the number of targets per trial and the nature of the final display were designed to reduce expectation that the final display in each trial was a target. This was necessary because, in three of the five experiments, the critical stimulus in the fourth trial was always presented with the final target of the trial.

The distractor set for the low load condition consisted of black letters and black digits and each target item was equally likely to be a red letter or a red digit (see Figure 1). In the high load condition, the distractor set consisted of black letters, red letters, and black digits, and all target items were red digits (see Figure 1). The majority of distractors in both conditions were selected at random with replacement from the full set of black letters. In order to keep the two conditions as similar as possible, the number of items in each RSVP sequence from the remaining distractor sets was restricted. In the low load condition, a maximum of 8 distractor items per trial were selected at random with replacement from a restricted pool of distractors consisting of a subset of 6 black letters (D, J, N, P, T, X) and the 6 black digits. In the high load condition, a maximum of 4 distractors per trial were randomly selected with replacement from a pool of distractors consisting of the full set of black letters and the full set of red letters. An additional maximum of 4 distractors were selected at random with replacement from a restricted pool formed from the union of 6 black digits and the subset of 6 black letters described above. Furthermore, in order to accurately code responses in the high load condition as target responses to red digits and not false alarms to red distractor letters, the position of the restricted distractor sets in the RSVP sequence was also controlled so that they did not occur within two distractor items of a target.

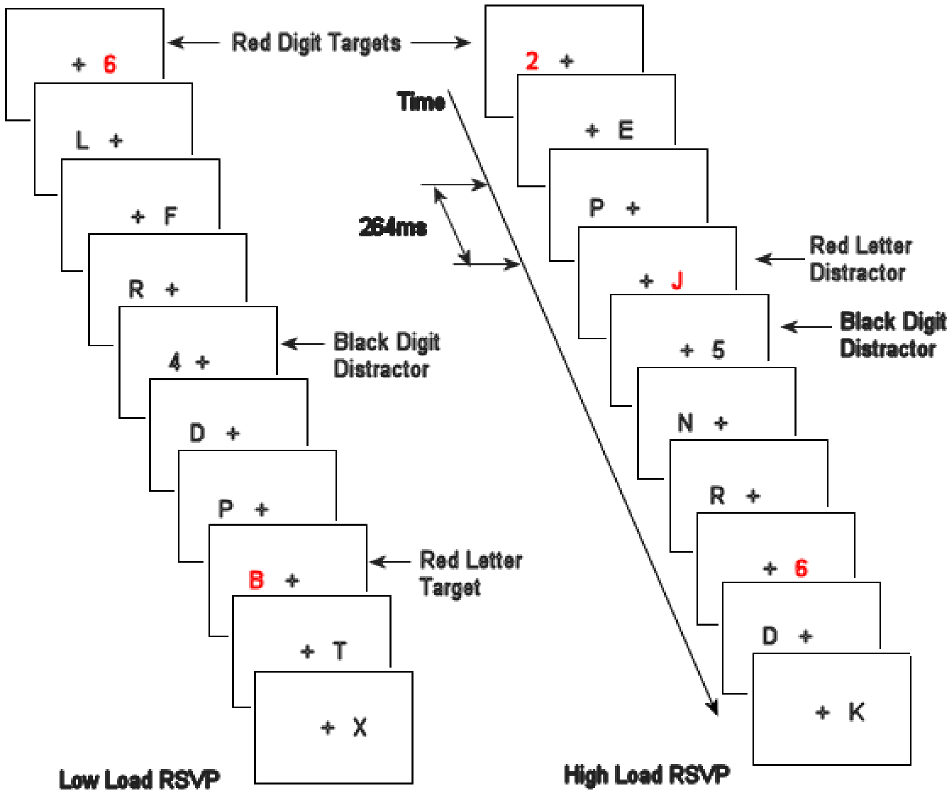

Figure 1. Schematic representation of the Low and High load RSVP tasks, targets and distractors.

Auditory stimuli were presented through two circular speakers located one either side of the computer screen at distances of 40cm below the screen, 45cm to the right or the left of the screen, and 25cm forward of the screen (all distances are measured from the centre of the computer screen and the centre of the speakers). The speakers were oriented 45° to face toward the participants head. Auditory stimuli were recorded, digitally compressed to 200ms and equated for peak amplitude using Cool Edit Pro (Syntrillium Software Corporation). Auditory distractor stimuli consisted of the same letter set used for the visual stimuli, and were presented in either a male or female voice (both of which were New Zealand English speakers) through a left or right speaker with equal probability at approximately 60dB.

Each of the visual letter and digit stimuli were randomly paired with an auditory stimulus and the pairs would always onset presentation together (for example when a red L was displayed on screen, the letter E in a male voice played through the left speaker).

On the last frame of the fourth 28-frame RSVP trial sequence (see Figure 1) a critical stimulus appeared in addition to the final target item which was a red digit in both low load and high load conditions. The final target and critical stimulus appeared on either side of fixation, with an eccentricity from fixation equal to that of the target and distractor stimuli (see Figure 2). The eccentricity of all critical stimuli was measured from the centre of the fixation cross to the horizontal centre point of the critical stimulus, and measured 2.39°. The critical stimulus was always presented with the auditory stimulus “N” in a male voice through a speaker location on the same side as the visual target digit (if the digit appeared on the right of the fixation cross, the auditory stimulus was also presented on the right). This was included in anticipation of conditions involving auditory critical stimulus words and pilot studies indicated the auditory word stimuli were best detected under full attention circumstances when paired with the letter N over any other letter.

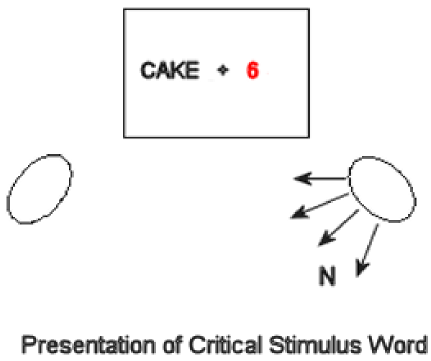

Figure 2. Schematic representation of the visual and auditory presentation of the word critical stimulus.

Design

Mack and Rock's (1998) inattention paradigm was modified with an RSVP so that the effects of cognitive load on the detection of an unexpected visual stimulus could be explored. The RSVP task incorporated two levels of cognitive load: low load (in which participants were instructed to respond to any red item) and high load (in which participants were instructed to respond only to red digits). Because the inattention paradigm requires participants to have absolutely no expectation that a critical stimulus will appear on the critical trial, a between subjects design was used. The location of the critical stimulus was counterbalanced across participants so that for half the participants it appeared on the left of fixation, and half on the right.

Procedure

In each trial the 28 stimulus item RSVP series was preceded by the presentation of the central fixation cross (1500ms) which then remained on screen throughout the task. Participants were instructed to maintain fixation on the cross throughout the trial. Each combination of visual and auditory stimuli was presented for 214ms with an inter-stimulus-interval of 50ms. Therefore each pair of stimuli would onset approximately 264ms after the onset of the preceding stimulus pair. Participants were instructed to push either of the two buttons on the response mouse as soon as they saw a target and to make their responses as quickly and as accurately as possible. In the low load condition participants were instructed to respond to any red item, whereas in the high load condition participants were instructed to respond to red digits only. Each trial would end with a blank screen

(1500ms) after the presentation of the final stimulus of the trial, followed by instructions to begin the next trial.

Each participant completed a total of 7 RSVP trial sequences beginning with two practice sequences, after each of which they could ask the experimenter questions if they did not fully understand the RSVP monitoring task. They then completed four experimental trials, the fourth of which was the critical trial where the critical stimulus was presented in addition to the fourth and final target for the trial. After the presentation of the critical stimulus either a visual mask or blank screen is present depending on the experiment (details to be given when appropriate). This was followed by a screen asking participants if they saw or heard anything different during the last trial. Participants were also instructed to respond yes by pressing a designated blue key on the keyboard ("x") or no by pressing a yellow key ("."). Once a response was made a second screen instructed participants to describe the difference they saw or heard as specifically as possible in writing on paper provided, or to write NA if they did not notice anything different about the last display.

Once participants had finished writing, the experimenter instructed them to press the space bar which then presented the instructions for the final full attention trial (the fifth experimental RSVP trial sequence). Participants were instructed not to complete the target monitoring task or make any responses. Instead they were instructed to determine if a visual critical stimulus (identified as word or shape depending on the experiment) had been presented on screen and to identify the stimulus (word or shape) (this was to encourage them to actively remember the stimulus because pilot studies had indicated that participants may notice the word, but quickly forget its identity). Participants were instructed to maintain visual fixation on the cross during the full attention trial. The full attention trial was identical to the critical trial with the same critical stimulus appearing at the same location as it had in the critical trial. Following the presentation of the full attention trial, a screen was presented instructing participants that if they saw a stimulus (word or shape) they should record it on the paper and press the blue keyboard key. Alternatively, if they did not see a stimulus, they were instructed to write NA and press the yellow key. Only participants who reported the correct stimulus on these trials were included in the data analysis.

Experiment 1

The purpose of Experiment 1 was first to demonstrate inattentional blindness to a word critical stimulus in an RSVP task, as well as to investigate the effect of cognitive load on the level of inattentional blindness.

Method

Participants

A total of 26 participants took part in Experiment 1. Data from one participant were excluded from analyses because of failure to detect the critical stimulus word under full attention conditions, and data from a second participant were excluded due to an error rate of 13%. This left a total 24 participants (7 male, mean age = 22 years, range = 17-43 years), with 12 in each of the two load conditions.

Apparatus and Stimuli

The apparatus for the presentation of the visual and auditory stimuli were the same as described in the General Method. The low and high oad tasks were those described in the General Method as we all target and distractor stimuli in the RSVP task. The critical stimuli used in Experiment 1 were the 4 letter words: CAKE, DUST and CORK (chosen due to their auditory clarity) presented visually in upper case. The words were presented in the same font and size as the letter and digit stimuli casting a visual angle of 2.96° when viewed at 50cm. The words were presented at either side of the fixation cross with the centre of the word measuring 2.39° from the centre of fixation (equal to the target and distractor stimuli). Each of the critical stimulus words was presented to an equal number of participants.

Procedure

The procedure was identical to that described in the General Method with the added detail that the presentation of the critical stimulus word was followed by a 1500ms blank screen to allow responses to the final target to be made. The 1500ms blank screen is modelled on Mack and Rock's (1998) experiments with IB to word critical stimuli.

Results and Discussion

In order to investigate the effects of cognitive load on the rate of IB, it is necessary to demonstrate first that a considerable proportion of participants failed to detect the critical stimulus when their attention was engaged elsewhere, and that cognitive load had been successfully manipulated such that the high load task was significantly more taxing than the low load task.

Word IB levels across both groups indicate that IB has been successfully demonstrated (see Table 1). In all experiments, IB to the critical stimulus is categorised at two levels: those who fail to detect any additional visual stimulus are categorised as having been 'blind' to the stimulus; and those who either correctly detect and identify the stimulus, or report detection specifically of a visual word (given that the question only asked if there participants saw or heard a difference) are categorised as ‘not blind’.

Across both the high and low load conditions 29% (7/24) were blind to the critical stimulus word. This is a considerably high level of IB, and is comparable to the 25% IB of a solid square critical stimulus reported by Mack and Rock (1998) in their cross arm length judgment task. Therefore, we can conclude that IB has been successfully demonstrated in the current RSVP task.

Analysis of target response times and error rates indicates that the load manipulation was effective. A straightforward way to treat the target response times would be to simply compute the median target response times for each participant and then compare the means for the two load groups. However it is necessary to exclude responses made to targets presented on the very last display of each RSVP sequence because, unlike other targets, these responses are made in the absence of following displays and distractor items. Also, responses made to targets appearing shortly before the final display may also still be in progress after the last display. Therefore only responses to targets made prior to the onset of the 1500ms blank screen, of which there were 13 (in Experiments 1-3, 14 in Experiments 4-5) were used to calculate the median response time for each participant.

Errors were categorised as either misses or false alarms. Misses occurred either when there was no response to a target, or a response occurred within 100ms of target presentation or more than 800ms following the onset of the target. False alarms were defined as responses made to distractors or responses made more than

800ms after the offset of a target.[2] Statistica 7.0 (Statsoft) software was used to calculate all statistics.

In Experiment 1, on average, participants in the low load condition responded to targets faster (M = 404ms, SD = 23.4ms) than those in the high load condition (M = 440ms, SD = 19ms), $t(22) = 4.22$, $p = .0004$. There was no significant difference in accuracy between the low load (M = 1.4%, SD = 1.4%) and high load conditions (M = 1.9%, SD = 1.6%), $t(22) = 0.92$, $p = .37$. However, because more errors occurred in the high load condition (with the longer response time) than low load condition, there are no speed accuracy trade-off concerns. Overall the error and RT results indicate a significant task difficulty effect and successful manipulation of cognitive load.

While both a considerable level of IB and a successful task manipulation have been demonstrated, there is no evidence of an effect of cognitive load on the level of IB. Table 1 provides a summary of the IB levels averaged over the three critical stimulus words presented under low and high load conditions.

The IB levels indicate little variation between the two load groups. A one-tailed Fisher's Exact test yielded no significant difference between the two load groups ($p = .5$). Therefore, although the RSVP task has produced levels of IB comparable with those reported by Mack and Rock (1998) and despite a significant task difficulty effect, there is no evidence that cognitive load has influenced the rate

[2] In Experiments 1-3 each participant was presented 13 response timed targets, and therefore 13 miss errors were possible per participant; and in Experiments 4-5, 14 response timed targets were presented thus allowing a possible 14 miss errors. There were 96 displays across all participants that did not contain a target and to which responses could potentially be classified as false alarms. However because responses occurring between 100 and 800 ms following a target are classified as target hits, purely distractor displays occurring within that window in the sequence must be excluded from those to which false alarms can potentially occur. Consequently, false alarms could occur on not more than 60 trials.

of detection of a critical word stimulus when presented unexpectedly and concurrently with a target in the RSVP task.

Table 1

Percentage of IB to critical stimulus words under conditions of low and high cognitive load in Experiments 1, 2, and 3.

	Low Load	High Load	Average
Experiment 1: word	25.0	33.0	29.0
Experiment 2: □	75.0	88.0	81.0
Experiment 3: ■	62.5	100.0	81.0

The results of this experiment are inconsistent with the predicted effects of cognitive load. Furthermore, the visual angle width of the word critical stimulus was much greater than that cast by the target and distractor letters (2.96° and 0.48° respectively). In order to control for this problem, the remaining experiments use two shape stimuli equal in size to the RSVP letter and digit stimuli. Experiment 2 uses a black outline square as the critical stimulus, and Experiment 3 uses a solid black square critical stimulus.

Furthermore, in their investigations of word detection Mack and Rock (1998) followed the critical word stimulus with a 1500ms blank screen, and in their investigations of shape detection, the critical shape stimulus was followed by a 500ms visual mask. Therefore, in the following experiments using shape critical stimuli, 500ms visual masks follow the presentation of the critical stimulus.

Experiment 2

Method

Participants

A total of sixteen participants took part in Experiment 2 ($N = 16$, 2 males, mean age = 23.4 years, range = 19-39 years).

Apparatus and Stimuli

The apparatus for the presentation of the visual and auditory stimuli were the same as described in the General Method as were the high and low load tasks and all stimuli with the exception of the critical stimulus. Experiment 1 used three words: *cake*, *dust* and *cork* as critical word stimuli. However in Experiment 2, the critical shape stimulus was a black outline square that subtended 0.48° in visual angle, which is equal to the width of the letter and digit stimuli. The critical stimulus outline square was presented with a visual angle eccentricity of 2.39°, measured from the centre point of the fixation to the centre point of the square. Unlike Experiment 1, a visual mask made up of black, white, and grey squares and rectangles was used in Experiment 2.

Procedure

The procedure for Experiment 2 was the same as described in the General Method with the added detail that a 500ms visual mask immediately followed the presentation of the critical stimulus.

Results and Discussion

Experiment 2 demonstrated a high level of IB with 13 (81%) of 16 participants failing to detect the critical shape stimulus. Therefore, IB of a black outline square has been successfully demonstrated.

In Experiment 2 there was also a significant difference in task difficulty between the low and high cognitive load conditions. The high load condition had significantly longer response times (*M* = 446ms, *SD* = 18.7ms) than the low load condition (*M* = 391ms, *SD* = 34.9ms), $t(14) = 3.94$, p =.002. No significant difference in error rates was found, $t(14) = 1.0$, $p = .34$. There is no evidence of a speed accuracy trade-off. Thus there is sufficient evidence to conclude that task difficulty has been successfully manipulated.

Consistent with Experiment 1, the IB level results of the present experiment indicate no effect of cognitive load on the detection of a black outline square when it is presented unexpectedly. Table 1 provides a summary of the IB levels for the critical shape stimulus under low and high load conditions. A high proportion of participants in both the low and high load conditions (6 of 8 participants, and 7 of 8 participants respectively) failed to detect the critical stimulus. The difference in IB levels failed to reach significance, $p = .5$ (one-tailed) using the Fisher Exact test. It can therefore be concluded that not only is cognitive load found to have no effect on the detection of an unexpected word in a RSVP task, but neither does it have an effect on the detection of an unexpected outline square shape stimulus.

The original demonstration of IB by Mack and Rock (1998) used a black solid square rather than a black outline square. Experiment 3 is identical to Experiment 2 except that a solid black square is the critical stimulus.

Experiment 3

Method

Participants

A total of twenty participants took part in Experiment 3. The data from four participants was excluded from further analysis because they failed to detect the critical stimulus in the full attention condition. This left 16 participants in Experiment 3 ($N = 16$, 5 male, mean age = 20.9 years, range = 18-27 years).

Apparatus and Stimuli

The apparatus for the presentation of the visual and auditory stimuli were the same as described in the General Method as were the high and low load tasks. All visual stimuli in Experiment 3 were identical to those described in the General Method. A solid black square shape with a visual angle of 0.48° served as the critical stimulus. The presentation of the critical stimulus was followed by a 500ms visual mask, modelled on that used by Mack and Rock (1998) in their investigations of IB to a shape critical stimulus.

Procedure

The procedure of Experiment 3 was identical to that described in the General Method with the added details of the critical stimulus and visual mask described above.

Results and Discussion

Consistent with the results of Experiment 2, Experiment 3 also demonstrated a high level of IB as 13 (81%) of 16 participants were blind to the critical and unexpected solid black square stimulus.

Cognitive load as calculated by a task difficulty effect has also been successfully demonstrated. The low cognitive load condition produced significantly faster response times (M = 399ms, SD = 16.5ms) than did the high cognitive load condition (M = 446ms, SD = 55ms), as indicated by a one-tailed t-test, $t(14) = 2.32$, $p = .048$. Error rates in the high load condition (M = 2.1%, SD = 2.8%) were not significantly different to those produced in the low load condition (M = 1.9%, SD = 1.8%), $t(14) = 0.14$, $p = .88$. There is no evidence of a speed accuracy trade-off. From these results, we are able to conclude that task difficulty has been successfully manipulated.

Consistent with previous experiments, the present experiment also failed to find a significant effect of cognitive load on the level of IB of an unexpected critical stimulus (see Table 1). Furthermore, the present results indicate a slight trend opposite in direction to the predicted effect derived from Lavie et al. (2004) with all 8 participants of the high load condition blind to the critical stimulus, but only 5 of the 8 low load participants were blind (see Table 1). However, this difference failed to reach significance using a one-tailed Fisher Exact test ($p = .1$). Therefore, considering these results and those of the previous experiments, we are unable to conclude support for a cognitive load effect on the detection of a critical stimulus that occurs unexpectedly and at the same time as a target stimulus.

A between experiment comparison of the overall IB rates found in Experiments 2 and 3 was conducted to determine whether filled and outline shapes varied in their propensity to produce IB. No difference between IB levels to a black outline square critical stimulus and a solid black square stimulus of the same dimensions was expected. As seen in Table 1, this hypothesis was supported as the two critical stimulus shapes had identical IB rates of 81%.

While there is no difference in IB levels between to the outline and solid critical shape stimuli, significantly more participants were blind to a critical shape stimulus than to a critical word stimulus (see Table 1). This difference in magnitude of IB is most likely due to the difference in size and saliency between the shapes and words. The critical shape stimuli cast visual angle widths of 0.48° whereas the visual angle of the critical word stimuli was 2.96°. Therefore, the word stimuli were more salient than the shapes, and had a greater sudden onset effect as much of the area they occupied was blank in all previous trials. Letters and digits are also more similar in nature to words than to geometric shapes. Therefore the word critical stimuli may have been in the attentional set (Most et al., 2005; Most et al., 2001) of the task leading to greater detection than the shape stimuli. Furthermore, recent research (Chen & Treisman, manuscript under review) has suggested that stimuli have a greater capacity to capture attention as their eccentricity increases. Therefore, as both the word and shape stimuli were presented with equal eccentricities from fixation that were measured from their centres, absolute eccentricity (from fixation to the word's widest point) of the word stimuli (3.87°) is greater than that of the shape stimuli (2.63°). Therefore, word stimuli have greater eccentricity, saliency and are related to the attentional set, thus they captured attention at a greater rate than the smaller critical shape stimuli.

Experiment 4

Experiments 1-3 all investigate IB to a critical stimulus that occurs at the same time as a target stimulus. Critical stimulus onset with a target is a situation consistent with all previous IB experiments in which the critical stimulus is presented while the participant is actively occupied in performing the target task, for example judging which line is the longer of the two in a cross formation (see Mack & Rock, 1998). Participants are then required to make their response before they are questioned about detection of the critical stimulus. It is possible that the failure to report the critical stimulus occurs because the processes involved in executing the response to the target (after the critical stimulus presentation) lead to amnesia (failure to remember) of the presentation of the critical stimulus (Wolfe, 1999); rather than a failure of pre-attentive and selection processes to detect it, as is implied by the term IB. In order to investigate this possibility Experiments 4 and 5 no longer present the critical stimulus in conjunction with a target, or during an attentional blink period (500ms) following a target, but instead present the critical stimulus with a distractor, during an attentional target monitoring period.

Method

Participants

A total of eight students participated in Experiment 4 (3 male, mean age = 20.9 years, range = 19-24 years). In order to be included in analyses in Experiments 4 and 5, it was necessary for participants to respond to the final target of the critical trial prior to the onset of the critical stimulus. All participants in both Experiments 4 and 5 met this criterion and are included in the analyses.

Apparatus and Stimuli

The apparatus for the presentation of the visual and auditory stimuli were the same as described in the General Method as were the high and low cognitive load tasks. All stimuli were identical to those described in the General Method with the added details of a 500ms visual mask following the final display of the RSVP stream, and the critical stimulus was a black outline square.

Procedure

The procedure was identical to that described in the General Method with two exceptions. Due to a programming error participants were mistakenly instructed that distractors and targets could occur at any of four locations: above, below, to the left or to the right of the fixation cross. However, targets and distractors continued to occur only in the same two locations to the left and right of fixation that were used in previous experiments. Secondly, the critical stimulus was no longer presented simultaneously with the final target of the critical trial. Instead the outline black square critical stimulus onset occurred simultaneously with a black distractor letter but only after two distractors had followed the previous target. This resulted in a 528ms period separating the onset of the last target and the onset of the critical stimulus. The goal here was to ensure that the critical stimulus did not occur within an attentional blink (or response period) following the final target of the critical trial. To ensure that the results reflect IB to a critical stimulus outside of a response period participants who failed to respond to the final target prior to the presentation of the critical stimulus were excluded from analyses.

Results and Discussion

Consistent with the previous results, task difficulty was again successfully manipulated. Mean response times under high cognitive load conditions (M = 482ms, SD = 65ms) were longer than those under low load conditions (M = 406ms, SD = 6.9ms) a difference that was almost significant, as indicated by a one-tailed t-test, $t(6) = 2.32$, p =.06. Furthermore, there was no significant difference in accuracy between the high (M = 1.4%, SD = 1.6%) and low load conditions (M =

0.7%, *SD* = 1.4%), $t(6) = 0.66$, $p = .26$. Speed accuracy trade-off is not an issue, and task difficulty has been successfully manipulated.

It is not possible to investigate an effect of cognitive load on levels of IB in the present experiments because, in contrast to all previous experiments that found considerable levels of IB to the critical stimulus, virtually no IB occurred in the present experiment (see Table 2). Of the 8 participants, only 1 person (low load) was blind to the black outline square when it appeared unexpectedly with a distractor and outside the previous targets response period.

Table 2

Percentage of IB to critical stimuli when presented in conjunction with a target or a distractor under low and high cognitive load conditions.

	Low Load	High Load	Average
Expt 2: Target onset □	75.0	88.0	81.0
Expt 4: Distractor onset □	25.0	0.0	12.5
Expt 3: Target onset ■	62.5	100.0	81.0
Expt 5: Distractor onset ■	63.0	88.0	75.0

A between experiment comparison of the IB levels found in Experiment 2 and those found in the present experiment allows us to evaluate the hypothesis that it is the attentional processes and not the demands of generating a response that lead to IB. If IB is due to attentional rather than response processes, then the conditions under which the critical stimulus is presented (either with a target and immediately prior to a response period; or onset with a distractor following a response period) will have no effect on levels of IB to a black outline square critical stimulus. Table 2 provides a summary of the IB levels for when the critical stimulus is accompanied by a target or a distractor. Under conditions of onset with a target and followed by a target response period (Experiment 2), 81% of participants (13/16) are blind to the critical stimulus. However, under conditions of onset with a distractor outside of a target response period (Experiment 4), only 12.5% (1/8) participants are blind to the critical stimulus. Distractor onset conditions relative to onset with a target appear to have significantly decreased the level of IB to an unexpected critical stimulus (two-tailed Fisher's Exact test, p =.002). This suggests that it is the demands of response execution and not pre-attentive selection processes that lead to amnesia of critical stimulus in attentional IB experiments.

However, there is an alternative explanation for these results. Due to a fault in programming, participants were mistakenly instructed that distractors and targets could occur at four possible locations instead of the actual two. This instruction is likely to have broadened the spatial area of attention, increasing susceptibility to additional stimuli. Furthermore, the contradiction between the instructions of the task and the reality of the task may have further increased susceptibility of participants to unexpected changes. Therefore, from the results of the present experiment, it is not possible to draw strong conclusions about the changes in IB levels and their relationship to the conditions of critical stimulus onset: whether it is presented with a target or distractor item.

Experiment 5

Experiment 5 offers a means to clarifying the interpretation of the results of Experiment 4, and further explores the relationship between IB to a critical stimulus and whether the critical stimulus is present with a target or distractor item. The present experiment replicates the distractor critical onset procedure used in Experiment 4, with two alterations. Firstly, participants were correctly instructed of the two (not four) location monitoring task, which allows for investigation of the possibility that the instructions led to a broadening of the size of the attentional field. Secondly, a solid black square critical stimulus was used instead of a black outline square. This was to allow for a direct comparison with the results of Experiment 3, and is not considered a problematic difference from Experiment 4 as the comparison of IB levels in Experiments 2 and 3 have indicated no evidence of any difference in IB between the two critical stimuli shapes.

Method

Participants

Eighteen students took part in Experiment 5. Data from two participants was excluded because of failure to detect the critical stimulus under full attention conditions. This left 16 participants (3 male, mean age = 24.4 years, range = 19-38 years).

Apparatus and Stimuli

The apparatus for the presentation of the visual and auditory stimuli were the same as described in the General Method as were the high and low cognitive load tasks. All stimuli were identical to those described in the General Method and used a black solid square shape critical stimulus followed by a visual mask presented for 500ms.

Procedure

The procedure was identical to that described in the General Method with the exceptions of the critical stimulus black solid square that would occur under distractor rather than target conditions. Note, unlike Experiment 4, participants were correctly instructed of the two location RSVP task.

Results and Discussion

In contrast with Experiment 4, the present experiment successfully demonstrated a considerable level of IB to the black solid square critical stimulus when it was presented in conjunction with a distractor but outside the response period of a prior target (see Table 2). Of the 16 participants, 12 (75%) failed to detect the critical stimulus under distractor conditions. When compared with the IB levels to the same critical stimulus under target presentation conditions (Experiment 3), no significant difference was found (two-tailed Fisher's Exact test, $p = 1$). Table 2 provides a summary of the IB levels to a black solid square critical stimulus under target (81%, Experiment 3) and distractor presentation conditions (75%, present experiment). Unlike those of the Experiment 2 and 4 comparison, these results suggest it is not the effort involved in making a response that leads to a failure to detect an unexpected black solid square critical stimulus, but rather the engagement of attentional processes in monitoring an RSVP task.

Experiments 4 and 5 differed in two ways: their critical stimulus (black outline square and black solid square respectively), and the instructions given to participants. The comparison of the IB levels in Experiments 2 and 3 reported earlier indicate no significant difference in IB patterns for the two different critical stimuli, therefore any difference in the IB patterns for Experiments 4 and 5 can be considered to be representative of an effect of the instructions given. Table 2 provides a summary of the IB results for Experiments 4 in which IB was nearly eliminated under instructions that stimuli could occur at four rather than the actual two locations; and Experiment 5 which found considerable IB to a black solid square under correct location monitoring instructions. The IB levels in Experiment 4 is significantly greater than that in Experiment 5 using the Fisher Exact test (two-tailed, $p = .006$). This result suggests that the difference in instructions had a significant effect on the levels of IB to a critical stimulus under distractor conditions and this finding contradicts the explanation offered following Experiment 4 that lack of IB in that experiment occurred because the onset of the critical stimulus did not occur with a target which required an overt response to be made.

As with previous experiments both the mean response times and error rates of the high load condition ($M = 441$ms, $SD = 31.4$ms, $M = 2\%$, $SD = 1.3\%$) were greater than those of the low load condition ($M = 405$ms, $SD = 20.8$ms, $M = 1.7\%$, $SD = 1.2\%$), with the response times difference reaching significance in a one-tail t-test, $t(14) = 2.73$, $p = .016$. While the difference in error rates failed to reach significance, the direction of the difference indicates speed accuracy trade-off is not an issue.

While Experiment 5 provides evidence supportive of a task manipulation, there is no effect of load on the level of IB to the solid square stimulus (see Table 2) as no significant difference in IB levels is found between the high and low load conditions (one-tailed Fisher's Exact test, $p = .28$).

It was hypothesised that greater levels of IB to an unexpected critical stimulus would occur under conditions of low cognitive load than under high cognitive load in the current RSVP monitoring task. However, no significant load effect was found in any of the experiments reported, regardless of stimulus type (word versus shape) or whether the critical stimulus occurred with a target or distractor item. When the IB results of all five experiments are collated and a comparison conducted between low and high load conditions (see Table 3 for summary) the trend is in the opposite direction to the expected cognitive load effect with the high load condition producing an overall IB level of 65% (26/40) while the low load condition produced a 50% (20/40) IB level. However, this difference failed to reach significance (one-tailed, Fisher's Exact test, $p = .13$) and therefore there is no conclusive evidence of an effect of cognitive load in the detection of an unexpected stimulus.

Table 3

Percentage of IB to critical stimuli across all experiments, under conditions of low and high cognitive load.

	Low Load	High Load
% IB	50	65

General Discussion

The present research aimed to investigate the effect of cognitive load on the detection of unexpected stimuli in an RSVP task. In order to do so, it is necessary to demonstrate inattentional blindness to unexpected stimuli in an RSVP task. The task used in the present research required participants to monitor an RSVP stream containing both red and black letters and digits which were presented randomly either side of a central fixation cross. On the final display of the critical trial, an unexpected stimulus was presented in conjunction with either a target or a distractor item. Four of the five experiments reported above demonstrated considerably high levels of inattentional blindness (ranging from 29% to 81% IB) to the unexpected stimulus. Therefore, the IB results of the present research provide strong evidence that the RSVP method used by the present research can be successfully used for investigating inattentional blindness.

The levels of IB found in the present research are very high in comparison to those found in the original Mack and Rock (1998) studies. In the present research, word critical stimuli produced IB levels of 29%, and shape critical stimuli, produced

IB levels of 75% to 81%. Using the 'inattention' paradigm and the cross line-length task, Mack and Rock (1998) found only 25% IB to shape critical stimuli. There is a marked increase in IB levels in the results of the present research, and there are several possible explanations. The present research used a two-location RSVP task as the primary selective attention task instead of the cross task. Because participants were required to monitor two locations instead of one, the RSVP task may have been more demanding on attentional resources than the cross task, leading to reduced detection of critical stimuli.

A second possible explanation for the high levels of IB found in the present research in comparison to those found in previous research is the attentional set relationship between the attended items and the unexpected stimulus. Using the 'selective looking' paradigm, Most et al. (2005) have demonstrated that unexpected stimuli similar to or within the same attentional set (for example, the same colour) as the target items are detected by 94% of participants, whereas only 6% of participants detect critical stimuli similar to the distractor set. Mack and Rock (1998) combined a black cross attended item with a black solid square critical stimulus, resulting in 25% IB. However, Cartwright-Finch and Lavie (2007) combined a green and blue version of the Mack and Rock cross task with a black outline critical stimulus and found a high 90% IB rate (when participants performed a line length discrimination task with the cross). The difference in IB levels in these two studies is likely to be due to the relationship between the attentional task and the critical stimulus. Mack and Rock's black critical stimulus was in the same attentional colour set as their black cross task, whereas Cartwright-Finch and Lavie's black critical stimulus was outside the blue and green attentional set of their cross task. Similarly, the present research combined black critical stimuli with black distractor items, and red target items. Thus, the critical stimuli of the present research were within the distractor set. Therefore, it is possible that the increase in IB level found in the present research is due to the relationship of the critical stimulus to the attentional and distractor sets used in the task.

Furthermore, it is possible to argue that the critical stimulus may have been further away from the locus of attention in the RSVP task than in the cross task. In the present research, the critical stimulus occurred 2.39° from the central fixation point which is similar to the critical stimulus used by Mack and Rock (1998) which was presented 2.30° from fixation. However, in Mack and Rock's cross task, fixation was located at the centre of the cross, and the cross also occupied the locus (or spotlight) of attention. In contrast, the RSVP task requires two locations to be monitored, each 2.39° from fixation. When the critical stimulus was presented, it occupied one of the locations, and a task item (either target or distractor) occupied the other, meaning a 4.78° separation between the items. Therefore, if the monitored item occupies the attended location, and then the critical stimulus may have been too far away to capture attention.

However, there are at least two reasons why the last argument may not comprise a valid explanation for the high rates of IB in the current experiments. Firstly, Chen and Treisman (manuscript under review) have recently found distractor interference to increase with eccentricity. In which case, if the above argument were true, the task used in the present study should have produced greater, not less, detection of the unexpected stimulus than previous research. Secondly, due to the nature of the RSVP task, it is not known in advance which of the two locations will contain the task item, therefore both locations are likely to be attended (either under a single attentional spotlight that encompasses both, or two small spotlights around each location). If both locations are attended, then the critical stimulus would have fallen within the focus of attention, similar to those used in Mack and Rock (1998). Thus, the increase in IB levels in the present research relative to previous studies is unlikely to be a result of increased eccentricity.

The cognitive load effect

While the present research demonstrated high levels of inattentional blindness using an RSVP task, it failed to find evidence of an effect of cognitive load on IB. According to the load theory of attention and cognitive control proposed by Lavie and her colleagues (2004), increases in cognitive load should lead to greater distractor interference and hence less IB to unexpected stimuli. The present experiment varied the cognitive load of the primary task by manipulating the basis upon which participants selected targets from the RSVP stream. In the low load condition, targets were selected on the basis of a colour judgment, which is a simple perceptual discrimination requiring little cognitive control. In contrast, the high load group selected targets on the basis of both colour and semantic category, requiring a higher level of cognitive processing and control. Although reaction time and accuracy measures indicated a successful manipulation of load, this difference in cognitive load was not reflected in levels of inattentional blindness to unexpected stimuli. No significant cognitive load effects were found in any of the five experiments, nor was there one when all five experiments were collated. These results are inconsistent with the predictions Lavie's cognitive control load theory.

Support for the cognitive load effect has been gained from Lavie et al. (2004) who used a set size working memory load manipulation in conjunction with a selective attention task to investigate the effect of cognitive load on distractor interference. They found distractor interference was greater in the large memory set size condition than in the small memory set size. However, much of the other research investigating the effects of cognitive load has failed to find support for Lavie's cognitive control load theory and its predictions. Two IB studies found increases in cognitive load to produce greater levels of IB (Fougnie & Marois, 2007; Simons & Chabris, 1999) contrary to Lavie's predictions. Similarly, although the present research did not find any significant load effects, the trend is consistent with previous research; more participants were blind to the critical stimulus in the high cognitive load condition (65%) than the low cognitive load condition (50%).

Furthermore, unlike the tasks used to investigate perceptual load, the task used by Lavie et al. (2004) to investigate cognitive load did not incorporate the load manipulation into the selective attention task itself. Instead, a dual task situation was created in which an unrelated working memory task (in which cognitive load was manipulated) was combined with a selective attention task. Therefore, the results may not reflect the effects of the cognitive load of the primary task, but the effect of dividing cognitive functioning between two tasks. The task used in the present research along with the task used by Simons and Chabris (1999) both manipulated cognitive load in single task situations, and both report results inconsistent with Lavie et al.'s (2004) cognitive load predictions. Therefore, it is possible that the cognitive control mechanism and its load effect as predicted by Lavie et al. is limited to dual task situations which heavily load verbal working memory.

Furthermore, neither cognitive nor perceptual load effects have been demonstrated in a situation in which the distractor items and/or unexpected stimuli (in the case of IB research) occur at an attended location as is the case in the task used by the current research. Two studies investigated load effects on Stroop interference using a Stroop task (which ensured both target and distractor information belonged to the same object, and therefore occupied the same location). Contrary to the predictions of Lavie's perceptual load theory, Chen (2003) found increasing the perceptual load of the Stroop task led to greater Stroop interference. Similarly, Gao, Chen and Russell, (2007) found that increasing working memory load while performing a Stroop task had no effect on the level of Stroop interference. The present study failed to find an effect of cognitive load on the detection of an unexpected stimulus that occurred at an attended location. Therefore, it is possible that the effects of both perceptual and cognitive load are limited to situations in which distractor items and unexpected events occur at non-attended locations.

Although the task used in the present research has strength by investigating cognitive load in a single (not dual) task situation, it could be argued that the load manipulation does not involve a variation in cognitive control load alone. The present research manipulated cognitive control load by having half of the participants select targets from an RSVP sequence on the basis of colour, and half on the basis of a colour and semantic categorisation conjunction. Lavie et al.'s (2004) theory argues that the cognitive control mechanism is involved in selection when the perceptual load of the task is low. In their investigation into the effect of perceptual load on IB levels, Cartwright-Finch and Lavie (2007) used a colour distinction task as a low perceptual load task. Therefore, the colour based selection of targets from an RSVP sequence used as a low cognitive load task in the present research can also be categorised as low perceptual load (as is necessary with for investigating Lavie's cognitive control mechanism). It could be argued that the high cognitive load task of the present research involves an increase in perceptual load as participants are required to select targets based on both colour and letter/digit category. However, (as mentioned in the introduction) Jonides and Gleitman (1972) demonstrated that the differences in the processing of letters and digits are due to their separate categories rather than due to the perceptual differences between them. Therefore, although the perceptual load between the two cognitive load groups in the present research may not be entirely equal, the difference is negligible in comparison to the difference in cognitive load.

Furthermore, although the present research involves an increase in the depth of cognitive processing required, it could be argued that it is not an increase in cognitive control load. While the semantic categorisation of letters and digits involves cognitive processing, cognitive control is also involved as participants in the high cognitive control load condition of the present research also have to inhibit responses to red non-target items. Participants in the low cognitive control load condition are required to make selections based on an early perceptual process and are only required to respond to any red item; therefore little response control is required to inhibit responses to black distractor items. In contrast, participants in the high cognitive control condition are required to respond only to red digits. They first have to select items early on a perceptual basis of red, and then categorise the red items as either letter or digit. Therefore, a greater level of cognitive control is required to inhibit responses to not only all black distractor items, but more so to the red letter distractor items. Thus, the present research has successfully manipulated cognitive control load in a single selective attention task situation, and has found no evidence of an effect of cognitive control load on the detection of an unexpected critical stimulus.

Perhaps the greatest limitation of the present research is an underestimation of the important role that attentional set plays in selective attention. Most and colleagues (Most et al., 2005; Most et al., 2001) have demonstrated the influential role that attentional set can play in selective attention in their investigations with sustained IB. They have shown that participants are more likely to detect an unexpected stimulus when it is similar to the attentional set of the primary task, and least likely to be detected with it is similar to the distractor set of the primary task. The present research neglected to consider the importance of the relationship between the unexpected critical stimulus and the attentional and distractor sets of the primary task. It is possible that the present research failed to find an effect of cognitive load because the critical stimulus was more similar to the distractor set of the primary task than to the attended set. The critical stimulus was always black, and in both low and high cognitive load conditions, the target items of the primary task were always red, and all black items were always distractors. Because both the high and low cognitive load conditions of the present research involved selecting red items (specifically red digits in the high cognitive load), it is likely that the critical stimulus always got discounted from selection at the same early level of perceptual selection in both the low and high load conditions. Therefore, the effect of cognitive load may have been masked by the relationship between the critical stimulus and the attentional and distractor sets of the primary task. This possibility could easily be explored by investigating the detection of an attended set critical stimulus (coloured red).

Limitations of Lavie's load theory of attention and cognitive control

While investigating the effect of cognitive control load on the detection of an unexpected stimulus the present research has also highlighted several limitations of Lavie's theory of attention, the first of which is her neglect to address the role of attentional set in the processing of irrelevant distractors. Comparisons of the IB levels found by Mack and Rock (1998), Cartwright-Finch and Lavie (2007), and in the present research clearly illustrates the extent to which attentional set can influence the detection of unexpected stimuli. As described earlier, when the critical stimulus is within the same attentional set as the primary task (Mack & Rock) levels of IB to the critical stimulus are much lower than when the critical stimulus is outside the attentional set of the primary task (Cartwrigh-Finch & Lavie), or within the distractor set (the present research). Most and colleagues (Most et al., 2005, Most et al., 2001) have also demonstrated the role of attentional set using the 'selective looking' paradigm. However, Lavie and colleagues do not address this obviously important aspect of attention in their load theory of attention and cognitive control.

A second limitation of Lavie's proposed theory is the difficulty involved in separating the two forms of load: perceptual and cognitive. Lavie and her colleagues propose there are two mechanisms involved in selective attention. The first is an early perceptual mechanism that selects on the basis of perceptual features, and the second is a cognitive control mechanism that is involved in maintaining top down attention on a primary task. However, the task used in the present research requires both selection on the basis of a perceptual feature, and the cognitive control of top down attention in order to perform the perceptual selection. The cognitive control mechanism is always going to be active when consciously participating in a selective attention task, as attention has to be consciously directed to and maintained on the task until completion. In essence, it is not possible to investigate low perceptual load in an experimental setting without invoking some aspect of cognitive control. Similarly, perceptual processing will always be involved in a selection task, but unlike cognitive processing, it can be limited to processing the stimuli and excluded from the actual ‘selection’ process. For example, in a selection task in which targets are selected on their meaning rather than any perceptual characteristic, perceptual processing is involved in processing the visual stimuli but not in the selection of targets. In order to establish the true effect of cognitive load, it needs to be investigated in a selection task with a cognitive load manipulation that does not involve loading working memory, or perception based selection. Such research has yet to be conducted.

The effect of critical stimulus presentation partner

As an additional consideration, the present research also investigated the detection of unexpected stimuli that occurred during an attentional task but in the absence of the attended object. Until recently, much of the research investigating inattentional blindness has primarily used either of two paradigms: Mack and Rock’s (1998) ‘inattention’ paradigm, or Neisser and Becklen’s (1975) ‘selective looking’ paradigm. While both of these paradigms are very useful for investigating the detection of unexpected stimuli under conditions of inattention, it is not possible to present the critical stimulus while the attended stimuli are absent. However, as demonstrated in Experiments 4 and 5, the RSVP task allows the critical stimulus to be presented either with a target item (like the ‘inattention’ and ‘selective looking’ paradigms), or with a distractor item. Interestingly, Experiment 5 showed that the level of inattentional blindness to critical stimuli presented in conjunction with a target was not significantly greater than when the critical stimulus presented in conjunction with a distractor.

On initial thought, this result is surprising and counterintuitive. Surely detection will be greater in the absence of a target item than in its presence. However, after further consideration it becomes clear that the attentional processes involved the two situations are the same and only the response processes differ. This is because in an RSVP task participants have to maintain attention throughout the duration of the sequence. Prior to the presentation of an item, participants are unaware whether the item will be a target requiring a response, or a distractor. Therefore, until the moment in which the item is presented, the active attentional processes are the same regardless of the type of item presented. Once the item is present, either of two processes is engaged: response execution if the item is a target and withholding of response when the item is a distractor. Because the critical stimuli were the same colour as the distractor items, when a critical stimulus is presented with a distractor, both may be dismissed as task irrelevant information before being processed to a level of reportable awareness.

Along with the cognitive load effect discussed above, it is likely that attentional set has also influenced the investigation into the effect of presentation partner. In the present research, the levels of IB to an unexpected stimulus presented with a target do not differ from the levels of IB when the unexpected stimulus is presented with a distractor item. If the critical stimulus presented in conjunction with a distractor item was similar to the attended target items (red in colour), it would be processed beyond the physical attribute of its colour, and be more likely to capture attention and reach conscious awareness. Therefore, it is possible that the present research was not sensitive enough to the role of attentional set to uncover an effect of presentation partner.

Further Research

The IB RSVP task used in the current research provides a good method for investigating the role of attentional set and similarity in attention capture and awareness. Because this method uses a selective attention task in which both target and distractor items are necessary, the relationship between the critical unexpected stimuli and the attended and distractor sets can be easily manipulated. It is possible to vary the degree of similarity between the critical stimuli and the target and distractor sets on the basis of many perceptual features such as colour and size, along with finer perceptual and cognitive discriminations by using letter, digit and symbol sets.

Many of the early theories about the nature of attention assumed attention to be a singular ‘spotlight’ or ‘zoom-lens’ which could select a location or object, and could vary in size (e.g. Eriksen & Yeh, 1985, Posner, Snyder & Davidson,1980). However, recent research (see Cave & Bichot, 1999, for a review) indicates that attention can be split across non-contiguous regions of space, illuminating multiple objects and/or locations. The current method has potential for investigating the nature of attention and its spotlights. Because the RSVP task allows for multiple locations to be monitored, it is possible to manipulate the extent, shape and number of attended locations. It is also possible to manipulate the location of the unexpected stimulus, allowing it to appear at an attended location, within an attentional spotlight, or outside of attentional monitoring completely. Consequent levels of IB would provide an indication of the allocation of attention to multiple objects and locations.

Conclusions

The present research set out to investigate the load theory of attention and cognitive control which claims to have provided a solution to the early versus late selection debate. It did so by developing a novel method of investigating IB, by combing an RSVP task with the 'inattention' paradigm. Consistent with the results of previous studies, the present research failed to find support for a mechanism of cognitive control that is affected by cognitive load.

Furthermore, the method developed for the current research allowed for a new IB investigation. The present research provides the first investigation into the detection of an unexpected stimulus when presented with a distractor item rather than a target item. Interestingly, the presentation partner did not affect the rate of IB to the unexpected stimulus. However, it is possible that the failure to find both an effect of cognitive load and an effect of presentation partner on the levels of IB could be due to the relationship between the attentional set of the RSVP task and the unexpected critical stimulus. Furthermore, the method developed for the current research shows potential for further investigations into visual attention and awareness.

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